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MODIFICATION AND UPDATING OF THE MANNED ACTIVITY SCHEDULING SYSTEM (MASS) FOR SHUTTLE AND SHUTTLE PAYLOADS ANALYSIS

VOLUME I
MODEL MODIFICATIONS

By R. C. Ring

April 1973

Prepared under Contract No. NAS1-11674 by
CONVAIR AEROSPACE DIVISION OF GENERAL DYNAMICS
San Diego, California
for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PREFACE

This report is Volume I of the final report on Contract NAS1-11674, Modification and Updating of the Manned Activity Scheduling System (MASS) for Shuttle and Shuttle Payloads Analysis, conducted for the National Aeronautics and Space Administration, Langley Research Center. Volume I describes the modifications made to the MASS computer models. Volume II covers the analysis of Advanced Technology Laboratory payloads conducted with the updated MASS.

The Langley Manned Activity Scheduling System (MASS), shown in Figure 1, is a family of seven operational digital computer programs developed to provide tools for in-depth space mission planning and to aid in achieving efficient use of resources. The models and their associated data libraries were initially structured around the Manned Orbital Research Laboratory (MORL) and other space station studies during the mid- and late 1960's. The system has been continually updated and refined to be responsive to NASA's needs. MASS is currently capable of analysis of a wide variety of space system concepts including space shuttle sortie missions.

The MASS set of computer models mathematically simulates the space system by scheduling all mission activities under the constraints of resource availability and system capability. Manned space system concepts are composed of an integrated vehicle including subsystems, payload, man, and expendables. To adequately simulate the space mission, all elements of these systems, their operational flow, and their rules of operation were described and represented by mathematical relationships. Scheduling algorithms were set up to account for schedule options and operational interactions of system elements. These mathematical relationships and scheduling algorithms, programmed for a high-speed digital computer, make up the MASS. The integrated MASS is used to support all phases of mission planning from preliminary design to on-orbit operations.

Libraries of system parameters such as vehicle capability, crew skills, and onboard activities are required inputs to the MASS. Outputs consist of detailed schedule information, tabulations of resource use, and scheduling problems encountered. The following paragraphs contain a brief description of the computer programs and their applications.

The Diagnostic and Listing program (D & L) provides a data check function to ensure input data consistency and compliance with constraints. A worded listing, provided by the D & L, shows all descriptors used to define the experimental, personal, and housekeeping activities to be carried out by the crew.

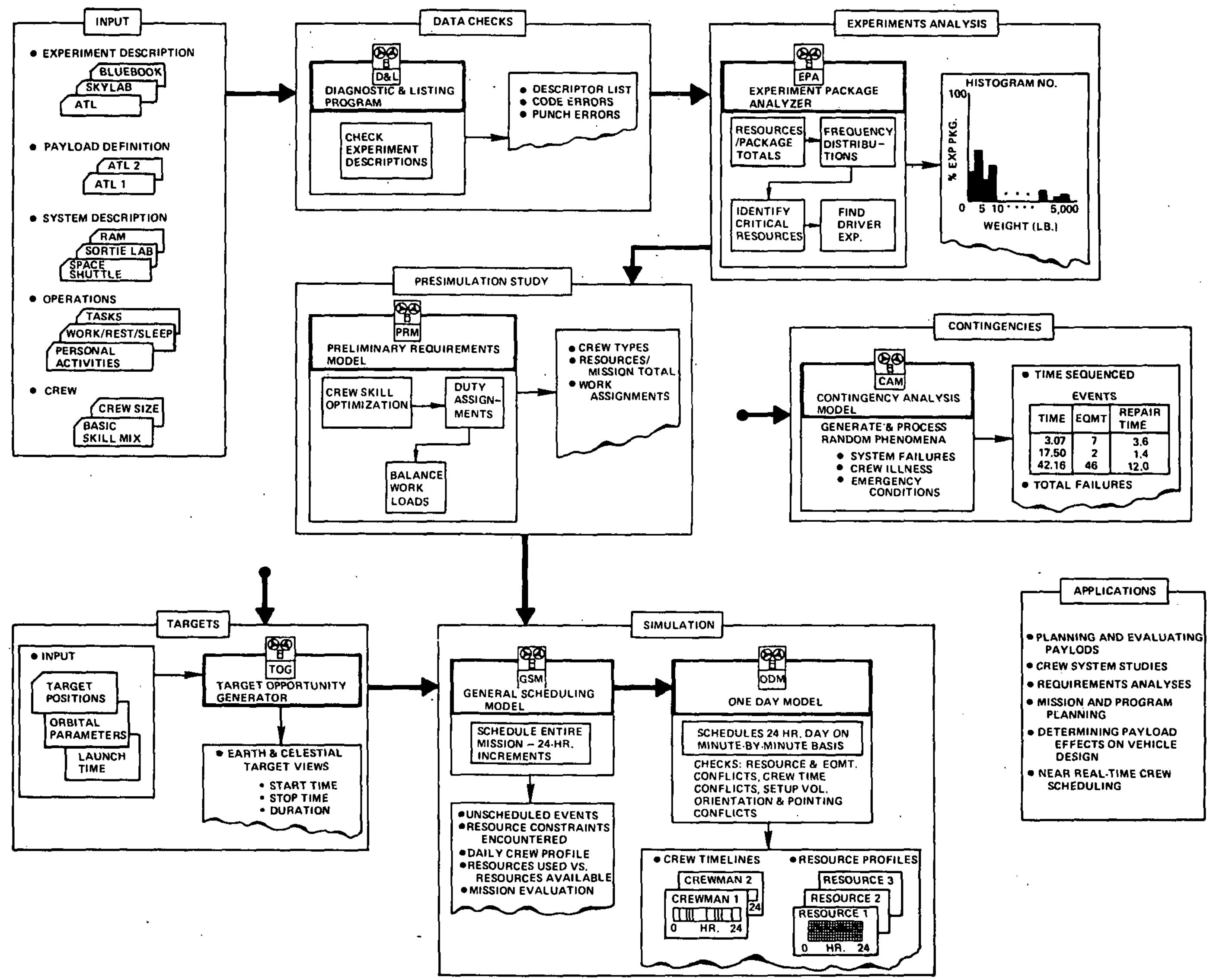

Figure 1. — Manned Activity Scheduling System (MASS)

Once the manned activities have been described and checked for consistency, the Experiment Package Analyzer (EPA) is used to determine their requirements for resources. The EPA calculates total resource requirements for the experiment package and generates frequency distributions for each. With this data the critical resources and the activities that place heavy demands on the system are identified.

Three of the MASS programs are special-purpose models that compute pre-simulation scheduling information required for the total space system analysis. The Preliminary Requirements Model (PRM) determines the mix of available crew skills that will best match the total skills necessary to perform the experiments. Based on these required skills, preliminary crew assignments to activities are made (assignments attempt to balance the workloads of the on-board crew). The results from the PRM provide a pre-simulation check on the match of available crew skills to mission requirements.

The second special-purpose model is required in cases where earth and/or celestial targets are to be viewed. The times and the duration of views over targets are computed by the Target Opportunity Generator (TOG). Taking target position, orbit parameters, launch time, and viewing constraints into account, the start and end time of each possible view is determined.

If unplanned or contingency events (crew illness, system failures, etc.) are to be considered in the scheduling analysis, the last of the special purpose models, the Contingency Analysis Model (CAM) is used. This program computes the expected number and time of occurrence of each contingency event using Monte Carlo simulation based on inputs of equipment mean time to failure. The primary outputs of the CAM are the events that occur, the time of occurrence, the resources required for repair (or in the case of crew illness, the decrease in available manhours), and a criticality classification.

Actual computerized scheduling for space mission simulation is accomplished by using the General Scheduling Model (GSM) and the One Day Model (ODM). The two models are complementary although each operates at a different level of scheduling detail for the same mission. The utility of each of these models is described below.

The General Scheduling Model (GSM) provides a schedule of experimental and nonexperimental activity for each mission day. Each event is scheduled separately,

adhering to the desired operations, but subject to the limited resources available at the time. The resource constraints checked by the GSM are:

Daily Constraints	Total Mission Constraints
Crew hours/day	Experiment equipment weight
Electrical energy (kWh/day)	Experiment equipment volume
Digital data storage	Shuttle pointing duration
TV and voice transmission (hours/day)	

After each event has been considered for scheduling, the GSM outputs the schedule for each mission day. The model also outputs a top-level summary of resources used for each mission day, total resources used for the mission, and diagnostics to indicate why (if appropriate) certain activities were not scheduled. Information for operating the One Day Model is processed by the GSM and passed on in the form of tape or card input.

The One Day Model (ODM) schedules activities over the 24-hour period of selected mission days. Activities to be scheduled by the ODM are those previously processed by the GSM for that day, and are therefore known to be consistent with total daily resource constraints considered. Experiment and housekeeping activities are scheduled throughout the mission day consistent with their required operations but subject to the following constraints:

- Crew availability
- Peak power levels
- Digital data storage
- Experiment support equipment availability
- Opportunities for viewing earth or celestial targets
- Nonconflicting vehicle orientation requirements

Tabulated output identifies the start and finish times of all scheduled events and provides timelines of resources used and daily totals. Activities not scheduled and the reasons for their omission are also noted. Graphic output from the ODM provides detailed crew timelines and selected resource use profiles.

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VOLUME I
MODEL MODIFICATIONS

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SUMMARY

The Langley MASS was modified and updated to include logic for efficient analysis of space shuttle payload operations. All MASS computer models were reviewed for compatibility with, and applicability to, the shuttle sortie mission. MASS modification efforts were concentrated on two computer programs, the General Scheduling Model (GSM) and the One Day Model (ODM). A new computer program, the DAYLIB Tape Processor, was developed to update the link between the GSM and ODM. The resulting MASS is an operationally efficient analytical tool that will allow a rapid assessment of shuttle and shuttle payload operations.

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1 INTRODUCTION

The space shuttle program represents the major thrust of the development of a national capability for routine operations in space. Currently, the final systems selections are underway and the major operational capabilities are being determined. Recent studies of shuttle payload carriers; i.e., Research and Applications Module (RAM), Shuttle Orbital Applications and Requirements (SOAR), Sortie Laboratory, and Advanced Technology Laboratory (ATL) identified the need for an analytical tool that would allow a rapid assessment of shuttle and shuttle payload operations. In response to this need, it was determined that the capability of the Langley Manned Activity Scheduling System (MASS) could be extended to include these operations.

Objective

The models that make up the MASS were structured with flexibility to allow changes that respond to the advances in research and development and the introduction of new space systems such as the space shuttle. The objective of the effort summarized in this report was to modify and update the current Langley MASS; in particular, the General Scheduling Model (GSM) and the One Day Model (ODM), to include logic for efficient analysis of space shuttle operations.

Approach

All MASS computer models were reviewed for compatibility with, and applicability to, the shuttle sortie mission. The GSM and the ODM were determined to be readily adaptable to analysis of shuttle and shuttle payload systems, resource availability, and resource use.

The GSM provides a high-level activity schedule for each day of the mission. Each experiment is scheduled separately, adhering to the desired activity profile, but subject to the resources available to the experiment at the time it is scheduled. After all experiments have been considered for scheduling, the GSM outputs the schedule for each mission day. The GSM also outputs a top-level summary of resources used for each mission day, total resources used for the mission, and diagnostics to indicate why (if appropriate) certain experiment activities were not scheduled. Information for further analysis of selected mission days is processed by the GSM and passed on to the ODM.

The ODM provides minute-by-minute schedules of activities over the 24-hour period of a selected mission day. Experiment activities to be scheduled on the ODM are those previously scheduled by the GSM for that day, and are therefore known to be consistent with the daily resource constraints considered by the GSM. Experiment and housekeeping activities are scheduled throughout the mission day consistent with the desired experiment activity descriptors (e.g., predecessor/successor relationship) but subject to resource and system constraints. Tabulated output provides start and finish times for all experiment activities and timelines of resources used. Also noted are activities that were not scheduled and the constraints these events encountered. Graphic output of selected activities and power profiles is available.

The following sections describe the modifications made to the MASS models to extend their capability, improve model efficiency, and improve ease of input/output.

2 GENERAL SCHEDULING MODEL MODIFICATIONS

Several additions and modifications were made to the General Scheduling Model (GSM) of the MASS. The GSM user's manual, Reference 1, describes in detail all aspects of the GSM. Significant GSM modifications are summarized below.

Payload Pointing

The capability to constrain the scheduling of events based on the precision pointing time required by these events was added to the GSM. Precision pointing time is defined as that time during which the system (e.g., shuttle) is required to provide pointing (for earth or celestial reference) at its maximum sustained capability. Each event to be scheduled specifies the number of hours of precision pointing required during an active day of the event. Experiment scheduling can then be constrained so that the total scheduled hours of pointing required for the mission does not exceed the time limit specified by program input. For conservative scheduling, pointing events are considered mutually exclusive; i.e., only one event can point at a time.

This capability is critical to analysis of the shuttle and shuttle payloads in a sortie mission. Experiment pointing time will be constrained by the capability of the shuttle and/or gimballed platforms to hold a precise pointing angle. This will have a direct impact on the percentage of work accomplishment on experiment payloads, particularly those with earth observations, astronomy, and communications/navigation experiments.

GSM payload pointing outputs include the daily pointing hours for each scheduled event, the number of times the pointing constraint was encountered and the total pointing hours scheduled.

Data-Handling Capacity

Current planning for the shuttle sortie mission suggests that the greater part of the data generated from experiment payload operation will be stored on board and returned to earth with the shuttle. A limited amount of payload data will be transmitted to earth from orbit; therefore it is of interest to establish that data storage requirements of potential shuttle payloads can be satisfied.

Digital data storage capability was added to the GSM as a resource scheduling constraint. The net system (e.g., sortie lab) data capacity for a given mission day is defined as the sum of the capacity remaining at the start of the day (prior to scheduling) and the daily transmission capability. Each event to be scheduled specifies the number of bits of digital data generated on an active day of the event. Event scheduling then takes into account total data accumulation and transmission during the mission. Scheduling is constrained by both the instantaneous data storage available and the transmission capability.

Program inputs required to exercise this capability are event data requirements and the system data storage capacity and daily transmission capability. Outputs include the number of times the storage and data transmission constraints were encountered during scheduling attempts and the remaining storage available for each mission day. For selected mission days, the digital data storage parameters are transmitted to the One Day Model (ODM) through the DAYLIB library.

GSM User Output

The GSM printed output was modified to show in a single display the event (experiment and task) activity for each mission day and for each crewman. Due to the short duration (7 to 30 days) of the shuttle sortie mission, this modification increases the clarity and readability of the GSM output with very little increase in the number of pages printed.

Figure 2 is a representative sample of this new output. Scheduled events are identified by a six-character name, shown in the left-most column of the printed output. For each event the GSM outputs the hours worked by each crewman, the power source used (LB: laboratory; M1: module 1; etc.), the electrical energy used (ac and dc power); voice communications, TV, and pointing hours used; and the digital data generated. Daily resource totals are given at the bottom of the page, where the indicator ALL under power source means the total energy for all power sources used by events that day.

This GSM modification was accomplished by combining the Planning Model Scheduling Processor (PMSP) with the GSM to obtain the desired output. Formerly, the PMSP program was a special-purpose model that provided intermediate printouts and a card-punched set of DAYLIB's (daily event activity and resource status libraries) used by the ODM. The PMSP function of punching DAYLIB card decks for the ODM has been retained in a new MASS model called the DAYLIB Tape Processor (DTP).

All other PMSP output functions have now been incorporated into the GSM, thereby eliminating the necessity for two computer runs to obtain required information.

GENERAL SCHEDULING MODEL   DATE 12/09/72   TIME 05.37.23.   PROBLEM 92572027   PAGE 43

10 TASK EVENTS AND 25 EXPERIMENT EVENTS SCHEDULED ON DAY 4

EVENT ID	HOURS WORKED BY MAN 1	HOURS WORKED BY MAN 2	POWER SRC	POWER DC KWH	POWER AC KWH	VOICE HOURS	T.V. HOURS	POINT HOURS	DIGITAL MEGABITS
S.H.1	1.00								
S.H.2		1.00							
M.P.1	1.00								
M.P.2		1.00							
P.H.1	.75								
P.H.2		.75							
EAT.1	3.00								
EAT.2		3.00							
M.C.1	.25								
M.C.2		.25							
EN.4B			LB	.00					43.2000000
MB.3B			LB	1.44					
MB.4D			LB	1.44					
CN.9B	1.50		LB	.18				1.50	
CN.9C		1.50	LB	.18				1.50	
CN.5B	.50		LB	14.40				.50	
CN.5C	2.00							2.00	432000.000
CN.3B		.50	LB	14.40				.50	
CN.3C		2.00						2.00	75600.0000
CN.7B	1.00		LB	3.60				1.00	86400.0000
EN.3A		1.00							
EN.3B			LB	2.00					
EN.3C		1.00							
MB.1B			LB	1.49					
EO.1B	.25		LB	2.75				.50	
EO.1C	.25		LB	.35				.50	
MB.2	.25	.25	LB	3.36					
PH.6B	.33		LB	.24				.33	
EO.2B	.25								983.000000
EO.2C			LB	.02				1.00	
PH.3	4.00		LB	.27					43.2000000
EN.3D		1.00							
EN.3E			LB	1.00					
EN.3F		1.00							
PH.1		2.00	LB	.40					3640.00000
TOTALS	16.33	16.25	ALL	47.52				11.33	603709.400

Figure 2. — Sample User Output for General Scheduling Model

DAYLIB Tape

A capability to write DAYLIB's for each mission day on a logical file (tape) for direct input to the ODM has been added to the GSM. This modification eliminates the need for punched-card libraries containing the daily event data and provides a direct link to the ODM. Table I defines the organization and logical records of the DAYLIB tape. The number -42803 separates data from different GSM problems on the tape.

Efficiency Changes in the GSM

Several modifications were made to the GSM in response to the requirement for suggested changes to improve efficiency and increase ease of use of the MASS models. Other changes were made to the organization and structure of the computer program to increase run efficiency by reducing core storage and/or run time requirements.

Library Tape. — Inputs to all MASS models consist of two types of data. Libraries contain information describing the events and systems being analyzed, while the problem deck contains information pertinent to the particular case being run. The method of inputting the data libraries to the GSM has been modified to eliminate the need for repeated use of large decks of punched cards. This added capability provides for the generation of a library input tape for repeated cases requiring the same basic input. The first time a particular set of libraries is used, it is input from cards. The GSM then places these libraries on tape and the tape is used for subsequent computer runs.

New libraries can be added to the tape at any time to build a data bank of program inputs. The data required for a particular case run is indicated by data library numbers in the case problem deck; the GSM will search the data-bank tape for the pertinent information. Particular libraries can be updated and replaced by reading in a new library with the same identification number. The library tape data bank can be established early in an analysis effort, making the balance of the effort much more efficient from the standpoint of user operations.

Priority/Payload Definition Library. — This modification provides the GSM with the capability of searching out event data for a particular set of events (i.e., a payload) from a library of descriptors containing a large number of events. Previously, for each different payload selected from an experiment package, a separate experiment descriptor library (EXPLIB) containing the characteristics of only those experiment events in the payload was required. For analyses involving more than one payload, operational efficiency was constrained by the required preparation of a specific EXPLIB for each. With the current GSM, only one EXPLIB describing all the experi-

TABLE I. — DAYLIB TAPE RECORDS

PROBLEM NUMBER OF GSM PROBLEM THAT GENERATED FOLLOWING DAYLIBS.

LIBRARY NUMBER OF FIRST DAYLIB FROM GSM PROBLEM.

FIRST DAYLIB FROM FIRST GSM PROBLEM.

LIBRARY NUMBER OF SECOND DAYLIB FROM GSM PROBLEM.

SECOND DAYLIB FROM FIRST GSM PROBLEM.

LIBRARY NUMBER OF LAST DAYLIB FROM GSM PROBLEM.

LAST DAYLIB FROM FIRST GSM PROBLEM.

-42803

PROBLEM NUMBER OF GSM PROBLEM THAT GENERATED FOLLOWING DAYLIBS.

LIBRARY NUMBER OF FIRST DAYLIB FROM GSM PROBLEM.

FIRST DAYLIB FROM SECOND GSM PROBLEM.

LIBRARY NUMBER OF SECOND DAYLIB FROM GSM PROBLEM.

SECOND DAYLIB FROM SECOND GSM PROBLEM.

LIBRARY NUMBER OF LAST DAYLIB FROM GSM PROBLEM.

LAST DAYLIB FROM SECOND GSM PROBLEM.

-42803

PROBLEM NUMBER OF GSM PROBLEM THAT GENERATED FOLLOWING DAYLIBS.

LIBRARY NUMBER OF FIRST DAYLIB FROM GSM PROBLEM.

FIRST DAYLIB FROM LAST GSM PROBLEM.

LIBRARY NUMBER OF SECOND DAYLIB FROM GSM PROBLEM.

SECOND DAYLIB FROM LAST GSM PROBLEM.

LIBRARY NUMBER OF LAST DAYLIB FROM GSM PROBLEM.

LAST DAYLIB FROM LAST GSM PROBLEM.

-42803

END OF FILE.

ments in the data bank from which potential payloads will be derived, is required. This single library can then be placed on the library input tape.

The capability for identification of a particular subset of data by the GSM was added by increasing the function of the existing Experiment Priority Library (EPILIB). The Experiment Priority Library is normally used to specify the relative priority of experiments — the higher the priority value the higher the scheduling priority. By specifying a zero priority, an event can be deleted from the payload. In this way the Experiment Priority Library can be used to identify the payload events and the relative scheduling priority of each.

Program Organization and Core Storage. — The organization and structure of the GSM have been changed to reduce overall program storage requirements. Routines associated with the logistics resupply for long duration missions were deleted, and computations for the generation of the DAYLIB tape and the daily summary of scheduling were added.

The GSM is organized in blocks of related computations called overlays. Overlay (0, 0) contains the main driver and other routines needed by more than one overlay. Overlays (1,0), (3, 0) and (4, 0) are called and executed when needed:

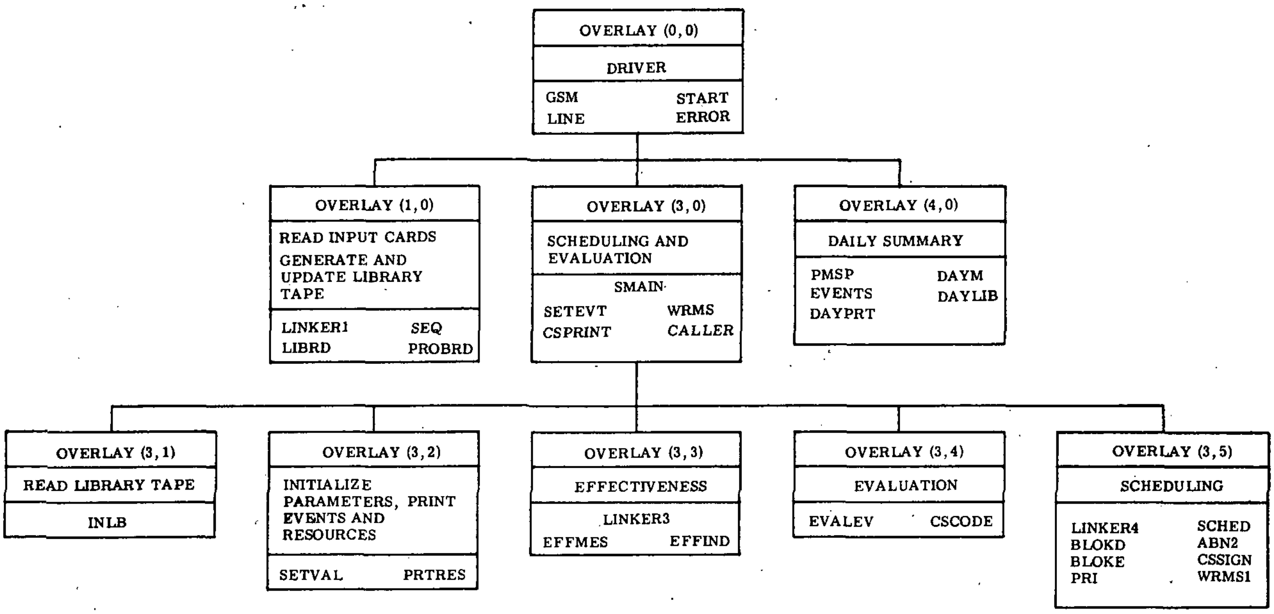
a. To read libraries and problem data (1, 0).

b. For scheduling and schedule evaluation (3, 0).

c. For generating the DAYLIB tape and daily summary of scheduling (4, 0).

Overlay (2, 0) formerly contained logistics and resupply computations and has been deleted. Overlay (4, 0) has been added and performs the type of functions previously performed by the Planning Model Scheduling Processor (page 6). Routine SEQ was moved from overlay (0, 0) to overlay (1, 0); routine PRTRES was moved from overlay (3, 0) to overlay (3, 2), and 80 percent of routine SMAIN of overlay (3, 0) was included in routine SETVAL of overlay (3, 2). These changes resulted in saving 1200 words of fixed program core storage. Figure 3 shows the resulting organization of the GSM.

The computer core storage required to execute the GSM is variable and depends on the maximum number of events to be scheduled, the maximum number of days in a mission, the maximum number of supply periods in a mission, and the maximum number of libraries on the input library tape. These quantities and the dimensions of related storage arrays are set in the GSM and PMSP routines of the GSM. By compiling the above routines when problem dimensions change, the user can reserve exactly the core storage required for his particular problem. Table II lists all the variable dimension parameters and fixed program capacities. The maximum possible



NOTE: THERE IS NO OVERLAY (2,0)

Figure 3. — Organization of General Scheduling Model

values of MXEVNT and MXNLIB are dependent only on the total core storage available.

For a typical sortie mission of seven days and 100 events, the GSM requires about 37,000 words of core storage.

TSKLIB/EXPLIB/MIXLIB Changes. — Several additional changes were made to the GSM to increase user efficiency and program capability.

Housekeeping and personal crew activities in the MASS are called "tasks" to distinguish between this type of crew event and events necessary to carry out scientific experiment objectives. The input of task libraries and the scheduling of tasks are now completely optional in running the GSM. The nature of the user's problem will determine which of the following four options to select:

a. No tasks to be scheduled, task libraries not required.

b. Tasks other than docking/arrival tasks to be scheduled; docking/arrival tasks not required in task library.

c. Tasks other than docking/arrival tasks to be scheduled; docking/arrival tasks required in task library.

d. All tasks to be scheduled; docking arrival tasks required in task library.

TABLE II. – GENERAL SCHEDULING MODEL, FIXED AND VARIABLE CAPACITIES

SYMBOL	DEFINITION	VALUE
MAXMD	MAXIMUM NUMBER OF DAYS THAT CAN BE IN A MISSION	1 TO 9000
MXBUNK	MAXIMUM NUMBER OF BUNKS IN LABORATORY	12
MXEVNT	MAXIMUM NUMBER OF EVENTS THAT CAN BE SCHEDULED	VARIABLE
MXLCNT	MAXIMUM NUMBER OF LINES PRINTED ON A PAGE	VARIABLE
MXNCRW	MAXIMUM NUMBER OF CREWMEN IN ROTATION PROFILE	60
MXNLIB	MAXIMUM NUMBER OF LIBRARIES ON LIBRARY TAPE	VARIABLE
MXNPER	MAXIMUM NUMBER OF SUPPLY PERIODS	1 TO 10
MXSKIL	MAXIMUM NUMBER OF SKILLS PER EVENT	6
MXSMKL	MAXIMUM NUMBER OF OVERLAPPING SKILLS IN A CHAIN	60
MXREVT	MAXIMUM NUMBER OF EVENTS IN A CHAIN WITH A REPEATED EVENT	60
(NONE)	MAXIMUM NUMBER OF CREWMEN TYPES	20
(NONE)	MAXIMUM NUMBER OF SCIENTIFIC AND TECHNICAL SKILLS	20
(NONE)	MAXIMUM NUMBER OF MODULE POWER SUPPLIES	8

A change to the weight/volume accounting in the GSM has been made. Formerly, weight and volume for an event were additive for each repetition of the event; this change ensures that event weight and volume are accumulated only once per mission.

The library of available crew types and skills (MIXLIB) is not required to run the GSM if the crew is to be made up of so-called "supermen"; i.e., every crewman fully proficient in all skills. Many preliminary analyses are conducted with such crewmen, with detailed definition of available skills coming somewhat later. An option in the problem input determines whether or not a MIXLIB is required.

The descriptors available for defining events for scheduling (EXPLIB and TSKLIB) in the GSM have been updated. Appendix A contains a list of the current event descriptors.

3 DAYLIB TAPE PROCESSOR

A DAYLIB Tape Processor (DTP) program was developed to replace the Planning Model Scheduling Processor (PMSP) function of punching DAYLIB card decks for input to the One Day Model (ODM). The other functions of the PMSP have been incorporated into the General Scheduling Model (GSM). The purpose of the DTP is to punch (from the DAYLIB tape generated by the GSM) DAYLIB library card decks for use as input to the ODM. A DAYLIB specifies the resources available on a particular mission day and the events in progress on that day. The relationship between the DTP, GSM and ODM programs of the MASS is shown in Figure 4.

The DTP will process one or more input problem decks. Each problem deck specifies the number of the GSM problem that generated the data and the number of groups of days (DAYLIB intervals) to be processed. Each DAYLIB interval specifies the days for which DAYLIB's are to be processed and if the DAYLIB's are to be printed, punched, or both printed and punched.

The ODM can now accept DAYLIB data from:

a. Manually generated DAYLIB library card decks.

b. DTP-generated DAYLIB library card decks.

c. GSM-generated DAYLIB tape.

The DTP was developed to retain full flexibility for DAYLIB inputs. Reference 1 contains full details on the use and operation of the DTP.

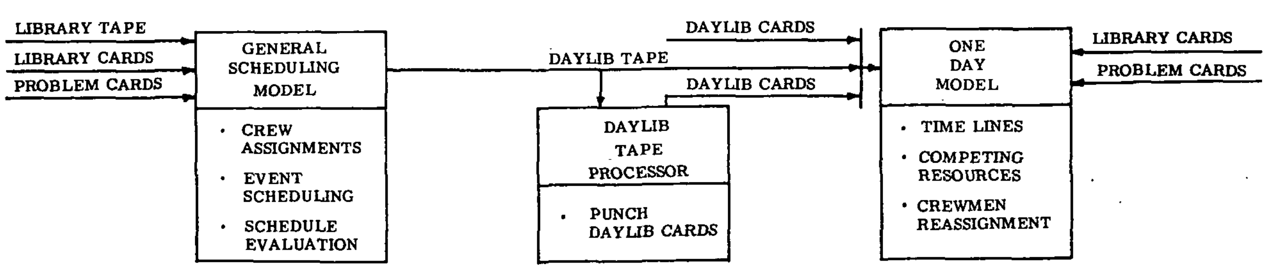


Figure 4. — Interface Between General Scheduling Model and One Day Model

4 ONE DAY MODEL MODIFICATIONS

The One Day Model (ODM) of the MASS was modified to incorporate the analysis of space shuttle sortie missions and to improve model efficiencies. Reference 2, the user's manual for the ODM, contains detailed information on all aspects of the ODM. Important modifications to the model are summarized below.

Viewing Opportunities

The ODM was modified to accept outputs from the Target Opportunity Generator (TOG) for priority scheduling. The TOG, operating separately from the other MASS models, provides the times for acquisition and loss of view of each target pass. These views are accepted as inputs by the ODM and are scheduled as fixed-time, fixed-position, high-priority events. Associated with this modification was the deletion from the ODM of all computations for determination of viewing opportunities for earth and celestial targets (see page 21). This change provides for much more flexibile view opportunity modeling and eliminates lengthy, costly, and repetitive view opportunity computations from the scheduling model.

The ODM can accommodate input view opportunities for data dumps, for communications, and for earth and celestial experiment targets. Typically for earth targets, a set of point and/or area targets is associated with a particular experiment (library event). View opportunities for these targets are a function of viewing orbit, launch date and time, mission day, and such constraints as elevation angle over the target and the sun incidence angle. View opportunities for a particular set of targets, under the appropriate constraints, can be determined from the Target Opportunity Generator (TOG) program. These views should then be edited to eliminate overlapping views (if any) and to provide a reasonable set of viewing opportunities as input to the ODM. Views for data dumps are automatically screened and combined by the ODM to produce an edited set of communication opportunities. Up to 25 viewing opportunities can be input for each program event.

Earth target views from low altitude earth orbit (e.g., on a shuttle sortie mission) are typically short (less than 10 minutes long). It may be unreasonable to assume that the crew can be ready and that equipment can be turned on and off instantaneously to accommodate these short bursts of activity. Therefore, a capability has been added to the ODM to input crew readiness, equipment warmup, calibration, and standby buffer time to the front end of the earth target view opportunities. Similarly a buffer time can be added at the end of the view opportunities to represent equipment shutdown and crew stand down. The situation is shown in Figure 5.

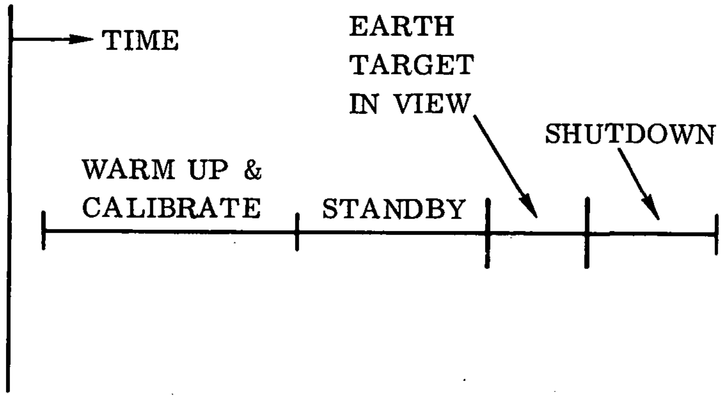


Figure 5. — Buffer Time for Earth Target Views

The number of events requiring targets is a program variable. The corresponding storage arrays for target parameters and viewing opportunities are of variable size, depending on the number of target events. Overall core storage requirements are thus variable, depending on user requirements.

Equipment Items

The capability of the ODM to account for common equipment was extended by increasing (from 15 to 100) the number of items that may be defined as equipment.

Equipment used by more than one event is called common equipment. The ODM checks common equipment availability and sharing compatibility as an event-scheduling constraint. Each event can now specify up to 12 required equipment items (EPRLIB library). The master list of available equipment (up to 100 items) is identified in the SYSLIB library. For each equipment item a 6-character equipment identifier, the number of units on board, and the simultaneous sharing compatibility with other events are defined. During event scheduling, if an event requiring a nonshareable equipment item is scheduled, the available units of that item are reduced by one. Subsequent scheduling of events, requiring that same nonshareable equipment item, is dependent on the availability of a unit. An equipment item classed as shareable can be shared by any number of events.

This capability can be used to ensure that mutually incompatible events are not scheduled at the same time. For example, if it is desired to isolate a g-sensitive experiment event from an acceleration-producing event, both events could specify a piece of dummy equipment defined as a single unshareable unit in the SYSLIB. Thus, the two events could never be scheduled simultaneously because of equipment sharing incompatibility.

The number of equipment items considered in a problem is a program variable that determines the size of associated storage arrays for equipment data. The user can thus set computer core storage requirements to a minimum for this new equipment capability.

Hangover Events

This modification adds the capability to process data automatically from events that extend beyond the end of the scheduling day (i.e., events that start on the scheduling day but end on the following day). Such data is prepared as input for analysis of activities on the following day and eliminates the need of manual hangover event data preparation.

The input parameter ITNHNG determines whether or not events will be allowed to extend past the end of the current scheduling day. If ITNHNG = 0, scheduled events must end before the end of the scheduling day. For ITNHNG = 1, events are allowed to end on the following day if they are started on the current day. If ITNHNG = 2, hangover events are allowed and the data is punched in card format for input to the next day's analysis.

Predecessor/Successor Capability

This change extends the capability of the ODM to permit chains (groups of events) to be related in predecessor/successor fashion. This capability can be used to relate the start of N event chains to the start of a common prececessor chain (e.g., one shuttle task must precede several payload tasks).

The predecessor-successor relationship for ODM events is the order in which events are to be carried out during the day. There may be as many as six events in a prececessor-successor chain; every event is considered to be part of a chain. If an event has no predecessor or successor, it is part of a single-membered chain. It is also possible in a predecessor-successor chain to specify a delay between events.

In additon to predecessor-successor relationships between events in chains, it is now possible for each chain of events to specify a predecessor chain of events. The user can specify a fixed or minimum time delay between the start of two chains. Figure 6 illustrates this capability. In the figure the start of three chains is related to the start of a single predecessor chain. There is no limit to the number of chains that may specify another chain as predecessor. This capability is limited to two levels; i.e., a chain which is a predecessor to another chain may not itself specify a predecessor chain.

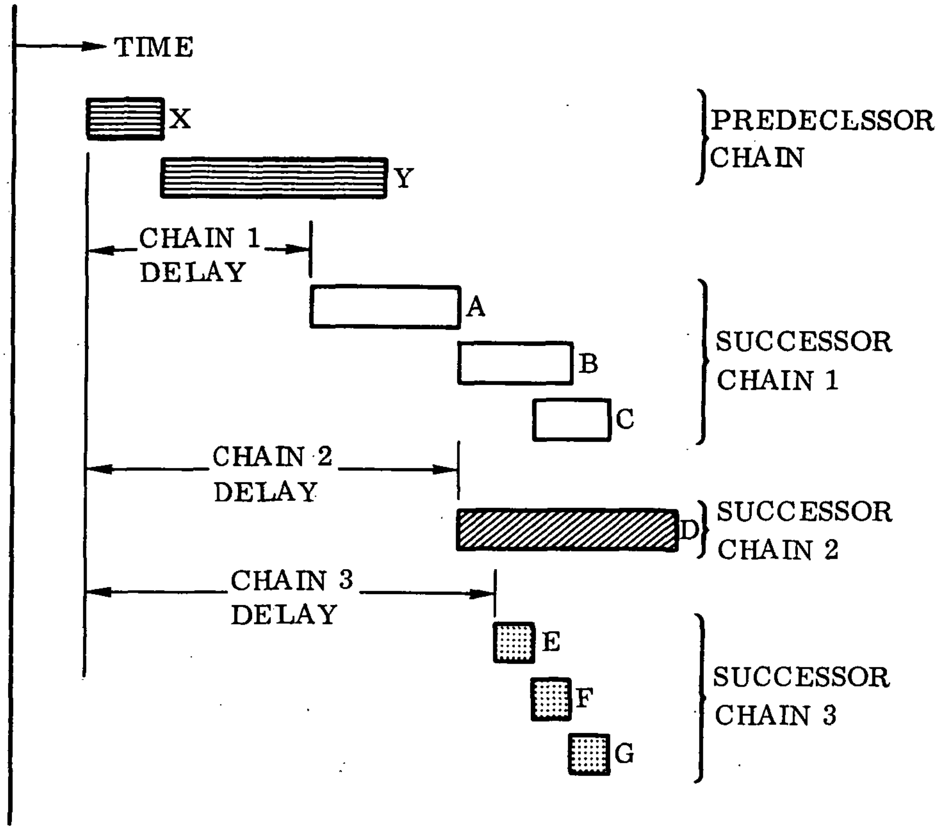


Figure 6. — Predecessor/Successor Relationship for Chains

Skill Delay

For the case of multiple-crewmen events, the capability to allow crewmen to start work at a specified time after the actual start of the event was added to the ODM. This feature permits more general event modeling.

Up to five crewmen (skills) associated with an event can now start at a specified time after the start of the event. An example of this capability is shown in Figure 7.

Partial Completion

The ODM has been modified to include the capability for partial completion of specified events to more realistically simulate events that do not require a specific duration (e.g., rest and recreation).

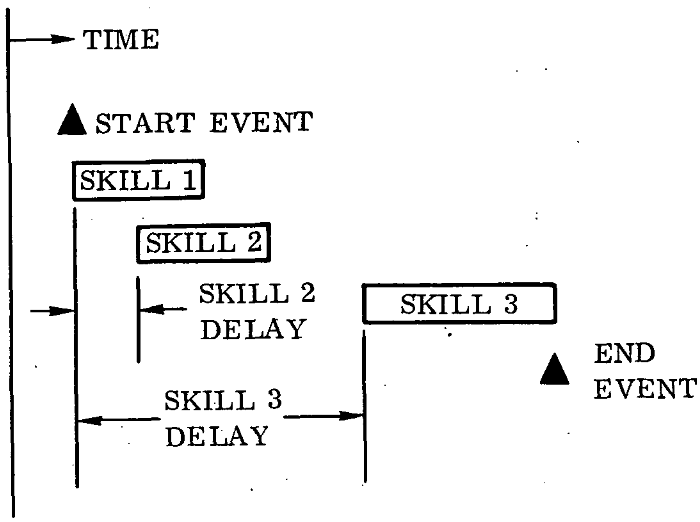


Figure 7. — Crew Skill Delays

The minimum acceptable fraction of a nonrepeating event's duration can be specified in the EPRLIB and TPRLIB libraries. For example, if the acceptable fraction of an event's duration is specified as 0.5, the event will schedule if half (or more) of the desired time is available. Partial completion of events in repeating chains is not allowed. ODM printed output will identify those events that are partially completed.

Efficiency Changes in the ODM

Several modifications were made to the computer program that make the use of the ODM more efficient. Some of these changes were made to the program input or output to improve user efficiency and clarity of the results. Other changes were made to the organization and structure of the computer program to increase run efficiency by reducing core-storage and/or run-time requirements.

Flight Mechanics. — All computations for determination of viewing opportunities for earth and celestial targets were deleted from the ODM. To replace the deleted flight mechanics routines, a capability was added to accept view opportunities as program inputs. This change eliminates the sometimes lengthy, costly, and repetitive viewing opportunity computations from the scheduling model, thereby reducing run time. The corresponding decrease in core storage results in greater run efficiency.

The modification resulted in the deletion of six ODM routines (ORBMEC, OVER, ERTHCO, CONV, SPCRFT, CELEST) and the deletion of six event descriptors formerly used to define and constrain the viewing of specific targets. Deleting the six

routines saved about 1600 cells of storage. Eliminating six event descriptors saves a maximum of about 600 cells, depending on the number of events to be scheduled.

DAYLIB Options. — The DAYLIB can be input to the ODM in two different forms (choice is made by option in problem input). The GSM can write the DAYLIB's for all mission days on a logical file; the data is identified by DAYLIB number and associated GSM problem number. This file can then be read directly into the ODM and searched for the DAYLIB corresponding to the mission day to be scheduled. Alternatively, the same GSM logical file can be read and processed by the DAYLIB Tape Processor (DTP) program and the appropriate DAYLIB's punched in card format for subsequent input to the ODM. This modification offers the user a way of bypassing the intermediate step of punching (on cards) the DAYLIB's from selected GSM mission days prior to input to the ODM. A library of DAYLIB's (from several different GSM problem runs) can be accumulated on the DAYLIB tape. The new, more direct link between the GSM and ODM thus contributes to overall analysis efficiency.

Program Organization and Core Storage. — The organization and structure of the ODM have been changed to reduce overall program storage requirements and to break up large, unwieldy routines where possible.

Like the GSM the ODM is organized in overlaid blocks of computations. The (0, 0) overlay contains the main driver program and routines generally needed by other overlays. This overlay is the foundation of the ODM and is always resident in core. Overlays (1, 0), (2, 0),,, (5, 0) are then called and executed sequentially for the basic tasks of:

a. Reading libraries (1, 0).

b. Reading problem data (2, 0).

c. Displaying the inputs (3, 0).

d. Scheduling events (4, 0).

e. Printing scheduling results (5, 0).

Overlay (4, 0) was divided functionally into three blocks. A small driver (4, 0) calls overlay (4, 1) for event preparation prior to scheduling, then calls (4, 2) for the separate task of event scheduling. Since overlays (4, 1) and (4, 2) are not required at the same time, overall core storage for the fourth overlay is reduced. In similar manner, the fifth overlay was split into four parts. A small driver (5, 0) calls (5, 1) for printing resource use, (5, 2) for printing activity profiles, and (5, 3) for plotting the scheduling results. All computations relating to data plotting have been collected in overlay (5, 3), eliminating several large storage arrays from other parts of the ODM, where they penalized the overall storage requirement. Figure 8 shows the resulting organization of the ODM.

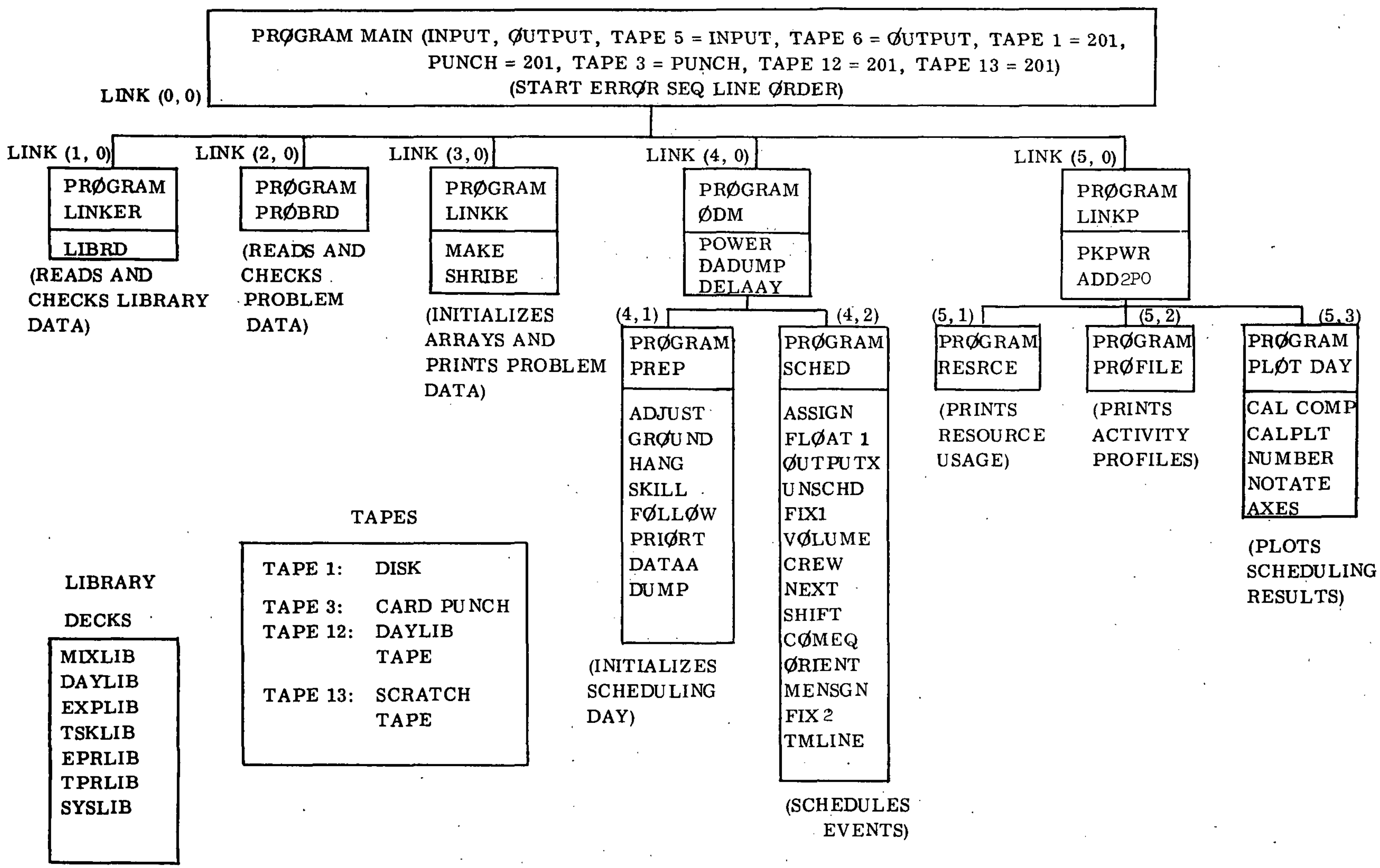


Figure 8. — Organization of One Day Model

Computer core storage required to run the ODM is variable and dependent on the maximum number of skills per event, the maximum number of events to be scheduled, the maximum of the number of events in the EXPLIB, TSKLIB, EPRLIB and TPRLIB libraries, the total number of data and experiment targets, the maximum number of equipment items, and the maximum number of resource intervals. These quantities and the dimensions of related storage arrays are set in DATA and COMMON statements in two routines (MAIN, LINKP) of the ODM. Compiling MAIN and/or LINKP whenever problem dimensions change, the user can reserve exactly that core storage required by his particular problem. Table III lists the program capacities of the ODM. The maximum possible value of MXEVNT is dependent only on total storage available.

TABLE III. – ONE-DAY MODEL PROGRAM CAPACITIES

SYMBOL	DEFINITION	VALUE
MXSK	MAXIMUM NUMBER OF SKILLS PER EVENT	(≤ 6)
MXSCHED	MAXIMUM NUMBER OF EVENTS TO BE SCHEDULED	(≤ 99)
MXEVNT	MAXIMUM OF THE NUMBER OF EVENTS IN (EXPLIB, TSKLIB, EPRLIB, TPRLIB)	
NTAR	TOTAL NUMBER OF DATA AND EXPERIMENT TARGETS	
MXEQP	MAXIMUM NUMBER OF EQUIPMENT ITEMS	(≤ 100)
NPNTMX	MAXIMUM NUMBER OF RESOURCE INTERVALS	(≤ 200)

* *

DELTA CORE STORAGE (DECIMAL) = 999*MXSK

+83*MXSCHED

+ 8*MXEVNT

+ 3*MXEQP

+ 45*NPNTMX

* *

These ODM organization and variable dimension changes reduced core storage for a schedule analysis of a typical sortie mission day from about 64,000 to 42,000 cells, including the storage associated with all the new capability added to the model.

Changes for The User. — Several additional changes were made to the ODM to increase program capability and user efficiency.

The program now computes the cumulative onboard digital data buildup that occurs when data being acquired (due to payload operations) exceeds system (e.g., shuttle) data-dump capability. The instantaneous onboard data is computed and included in the output resource status timeline. This capability is very useful for analysis of shuttle sortie missions during which most of the payload operations data will be stored on board.

A capability to specify the earliest start time (within the scheduling day) for an event was added to the ODM. This new event descriptor allows the user to relate the start of an event (or group of events) to a certain period of the day. For example, with this capability the user can specify that he does not want a mission planning task performed until the end of the work day, say after 5:00 p.m.

To make the ODM scheduling operations and results more easily understood by the user, a printout of program dimensions (defines required core storage) and a printout of the units (e.g., watts, kW, megabits, etc.) on all output parameters have been added to the ODM.

The descriptors available to define events for scheduling in the ODM have been updated. Appendix A lists the current set of event descriptors. An SC-4020 plot package was developed to display the results of event scheduling in the ODM. Appendix B contains a description of this capability.

5 CONCLUDING REMARKS

The Langley MASS was modified and updated to include logic for efficient analysis of space shuttle payload operations. All MASS computer models were reviewed for compatibility with, and applicability to, the shuttle sortie mission. MASS modification efforts were concentrated on two computer programs, the General Scheduling Model (GSM) and the One Day Model (ODM). A new computer program, the DAYLIB Tape Processor, was developed to update the link between the GSM and ODM. The resulting MASS is an operationally efficient analytical tool that will allow a rapid assessment of shuttle and shuttle payload operations.

6 REFERENCES

1. <u>User's Manual for the General Scheduling Model (GSM)</u>, Volume 1, 18 March 1973.

2. <u>User's Manual for the One Day Model (ODM)</u>, Volume II, 18 March 1973.

APPENDIX A

EVENT DESCRIPTORS

Currently 82 descriptors are available to describe events for scheduling in the MASS. Figure 9 lists all the descriptors, which are displayed in the required card input format for the EXPLIB/TSKLIB and EPRLIB/TPRLIB libraries. These forms are very useful in preparing the data bank (coding the libraries) required to run MASS.

EXPLIB/TSKLIB

1–6	7–12	13–18	19–24	25–30	31–36	37–42	43–48	49–54	55–60
EVENT ID	ALPHA NUMERIC DESCRIPTOR			PREDECESSOR/ SUCC. OPTION	PARTIAL COMP OPTION	OUTPUT SUM OF PHASES	ATTITUDE REQUIRED		ACTIVITY PROFILE FLAG
EVENT DURATION	NUMBER ACTIVE DAYS	NUMBER ACTIVE PERIODS	NUMBER INACTIVE DAYS	FIRST DAY ACTIVE/INACTIVE	FORCE START DAY	PREDECESSOR OR SUCC. DELAY	PREDECESSOR	PREDECESSOR OR SUCCESSOR	
NUMBER TIMES TO REPEAT	MIN. DELAY TO NEXT REPEAT	MAX. DELAY TO NEXT REPEAT			CONSECUTIVE EVENTS TO REPEAT	SUCCESSOR TO REPEAT REFER.	POINTING HOURS		
NUMBER SKILLS	1ST SKILL TYPE	1ST SKILL HOURS	2ND SKILL TYPE	2ND SKILL HOURS	3RD SKILL TYPE	3RD SKILL HOURS	4TH SKILL TYPE	4TH SKILL HOURS	5TH SKILL TYPE
5TH SKILL HOURS	6TH SKILL TYPE	6TH SKILL HOURS	AC STAND BY POWER WATTS	AC OPERATING POWER WATTS	AC OPERATING POWER HOURS	AC PEAK POWER WATTS	AC PEAK POWER HOURS	AC PEAK POWER DELAY HOURS	DC STAND BY POWER WATTS
DC OPERATING POWER WATTS	DC OPERATING POWER HOURS	DC PEAK POWER WATTS	DC PEAK POWER HOURS	DC PEAK POWER DELAY HOURS	VOICE HRS/DAY	TV HRS/DAY	DIGITAL DATA MEGA BIT/DAY	LOGISTICS WEIGHT UP	LOGISTICS VOLUME UP

EPRLIB/TPRLIB

1–6	7–12	13–18	19–24	25–30	31–36	37–42	43–48	49–54	55–60
EVENT ID	PREDECESSOR WITHIN CHAIN	SUCCESSOR WITHIN CHAIN	SUCCESSOR DELAY HOURS	EVENT LØCATION	EQUIPMENT ITEM 1	EQUIPMENT ITEM 2	EQUIPMENT ITEM 3	EQUIPMENT ITEM 4	EQUIPMENT ITEM 5
EQUIPMENT ITEM 6	EQUIPMENT ITEM 7	EQUIPMENT ITEM 8	EQUIPMENT ITEM 9	EQUIPMENT ITEM 10	EQUIPMENT ITEM 11	EQUIPMENT ITEM 12	SKILL 1 DELAY HOURS	SKILL 2 DELAY HOURS	SKILL 3 DELAY HOURS
FIRST EVENT OF PREDECESSOR CHN			FIXED TIME - POSITION FLAG	FIXED START TIME HOURS				PARTIAL COM- PLETION FLAG	WORK AREA VOLUME FT 3
CHN DELAY FROM PREDECESSOR HRS			NUMBER OF REPEATS	MINIMUM REPEAT DELAY HOURS	EARLIEST START TIME HOURS		SKILL 4 DELAY HOURS	SKILL 5 DELAY HOURS	

Figure 9. — Event Descriptor Form

APPENDIX B

SC-4020 PLOT PACKAGE FOR ONE DAY MODEL

An SC-4020 plot package was developed to display the results of event scheduling in the One Day Model (ODM). This capability for efficient assessment of scheduling results has proved to be extremely valuable in analysis of shuttle payload operations.

Using data generated by the ODM program, the plot routine produces a SC-4020 data plot illustrating the following scheduled resource activities:

a. Dc electrical power level.

b. Onboard digital data.

c. Crew activity.

In addition, the total resource use (for the entire day) is displayed. Figure 10 is a sample plot produced by the SC-4020 plot package. The plot displays resource and crew activity for a typical day during a shuttle sortie mission. The experiment payload is one of a set of Langley advanced technology payloads.

The dc electrical power level in kilowatts is presented as a power profile that ranges from either 0 to 4 kW or 0 to 8 kW. If the peak power in the data to be processed is less than 4 kW, the power profile ranges from 0 to 4 kW; otherwise the power profile ranges from 0 to 8 kW.

The second profile is a semilog plot of the onboard digital data (data dumps accounted for) in megabits. The vertical log scale consists of 4 decades automatically fixed in successive powers of ten, depending upon the largest data value. The maximum value is assumed to be 10^4 megabits unless a larger value is observed.

Activity profiles for up to six crewmen can be accommodated on the plot. A heavy dark horizontal line between two short heavy vertical lines indicates that a crewman is working, eating, or sleeping during this time interval. The specific activity performed by the crewman is identified by a six-character label.

The overall daily activity is summarized on the far right of the SC-4020 data plot. The total dc electrical energy in kilowatt hours is shown at the right of the power profile. Immediately to the right of the onboard digital data profile is the total digital

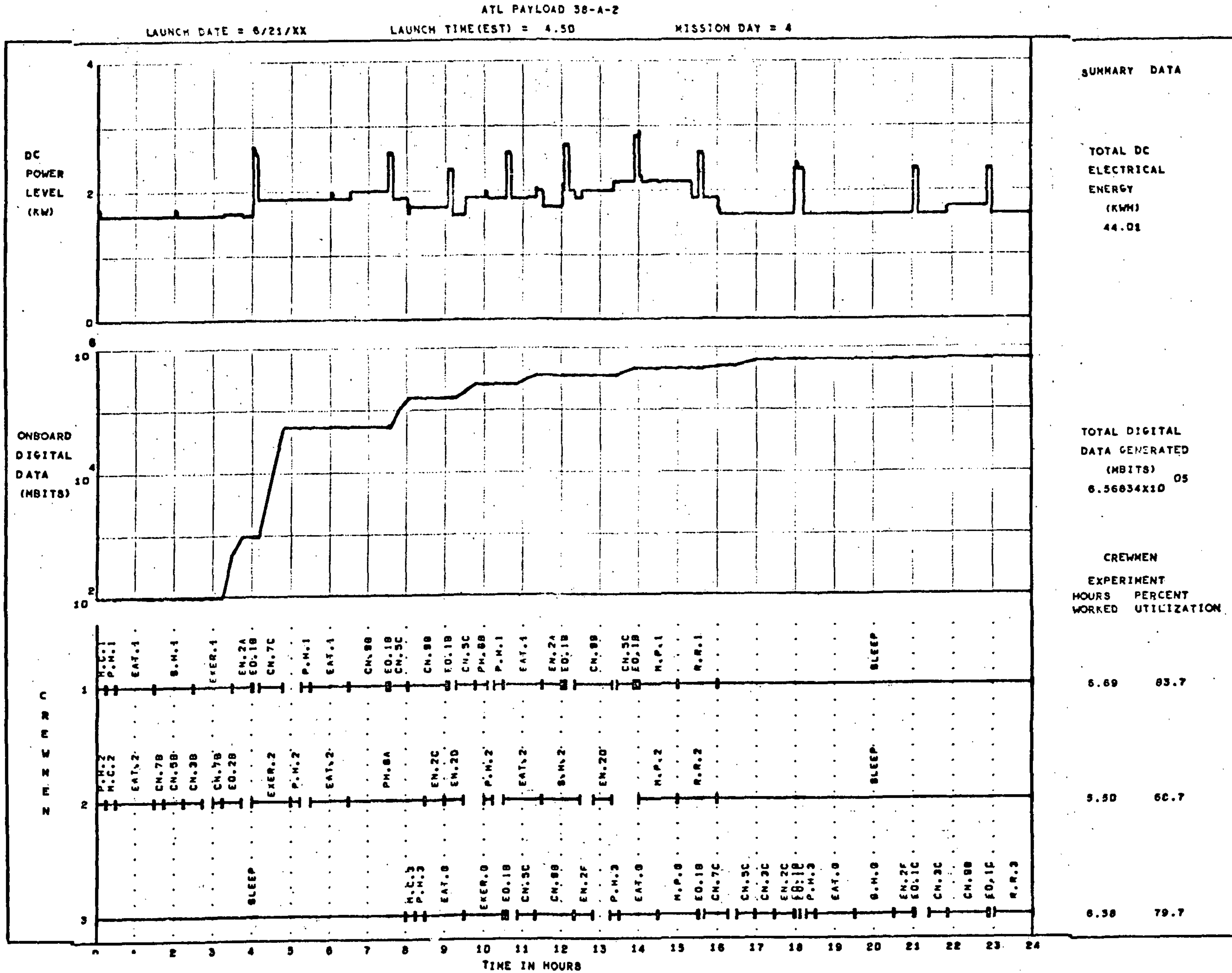


Figure 10. — SC-4020 Plot of One-Day Model Schedule

data generated in megabits. To the right of the crew activity is the total number of hours each crewman worked on experiments and his percent use determined from

$$\% \text{ use} = \frac{\text{Number hours worked on experiments}}{\text{Number hours available to work on experiments}}$$

The plot can be displayed on one, two, four, or six pages corresponding to 24, 12, 6, and 4 hour intervals. The user can select the format he desires to satisfy the requirements of his particular problem.

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13. ABSTRACT

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Scheduling Models						
Sortie Mission Payload Simulation						
Experimental Scheduling						
Resource Timelines						